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Scale-Dependent Friction and Damage Interface law: implications for effective earthquake rupture dynamics and radiation

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Propagation and radiation of an earthquake rupture is commonly considered as a friction dominated process on fault surfaces. Friction laws, such as the slip weakening and the rate-and-state laws are widely used in the modeling of the earthquake rupture process. These laws prescribe the traction evolution versus slip, slip rate and potentially other internal variables. They introduce a finite cohesive length scale over which the fracture energy is released.

However faults are finite-width interfaces with complex internal structures, characterized by highly damaged zones embedding a very thin principal slip interface where most of the dynamic slip localizes. Even though the rupture process is generally investigated at wavelengths larger than the fault zone thickness, which should justify a formulation based upon surface energy, a consistent homogeneization, a very challenging problem, is still missing. Such homogeneization is however be required to derive the consistent form of an effective interface law, as well as the appropriate physical variables and length scales, to correctly describe the coarse-grained dissipation resulting from surface and volumetric contributions at the scale of the fault zone.

In this study, we investigate a scale-dependent law, introduced by Raous et al. (1999) in the context of adhesive material interfaces, that takes into account the transition between a damage dominated and a friction dominated state. Such a phase-field formalism describes this transition through an order parameter. We first compare this law to standard slip weakening friction law in terms of the rupture nucleation. The problem is analyzed through the representation of the solution of the quasi-static elastic problem onto the Chebyshev polynomial basis, generalizing the Uenishi-Rice solution. The nucleation solutions, at the onset of instability, are then introduced as initial conditions for the study of the dynamic rupture propagation, in the case of in-plane rupture, using high-order Spectral Element Methods and non-smooth contact mechanics. In particular, we investigate the implications of this new interface law in terms of the rupture propagation and arrest. Special attention is focused on radiation and supershear transition. Comparison with the classical slip weakening friction law is provided. Finally, first results toward a dynamic consistent homogeneization of damaged fault zones will be discussed.

Raous, M., Cangémi, L. and Cocou, M. (1999). A consistent model coupling adhesion, friction and unilateral contact', Computer Methods in Applied Mechanics and Engineering, Vol. 177, pp.383-399.